Acoustic Scattering from Heterogeneous Rough Seabeds

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LONG-TERM GOALS

The goals of this research is to better understand the physics and mechanisms of sound-seabed interaction, including acoustic penetration, propagation, attenuation and scattering in marine sediments.

OBJECTIVES

Scientific objectives of this research is to assess the importance of different mechanisms of seabed scattering and their interactions, and to provide their physically understandable description at mid- and high-frequencies. Also, the research will contribute to modeling and inversions for the ASIAEX program for studying shallow water reverberation, and emphasizes the physics of bottom reverberation. Specifically, this research will provide methods for direct testing of hypotheses for the dominant mechanisms of seabed scattering.

APPROACH

There are different scattering mechanisms, which are generally can be attributed to two different types of seabed medium irregularities: volume heterogeneity such as continuous fluctuations of the sediment acoustic parameters and discrete inclusions (rock, shell hash, etc), and roughness of the water-sediment interface. The two mechanisms of seabed scattering, surface roughness and volume heterogeneity, can operate at the same time, and thus methods for their separate identification are of practical importance.

In this research, a correlation method has been developed, which permits separation and identification of volume and surface components of the scattered field. The method involves measurements of spatial

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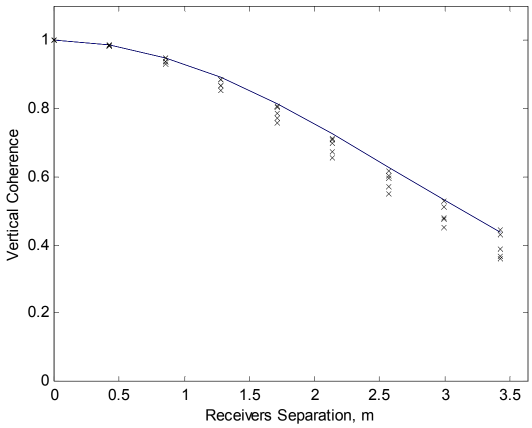
coherence of the field with a vertical linear array located near the source. Additionally, it allows measurement of the volume scattering strength and sound attenuation in sediment, quantities that are normally not separable in reverberation data. Thus, it provides, in particular, a new means of measuring the frequency dependence of attenuation for testing current models, some of which predict linear dependence while others predict more complicated dependence on frequency.

WORK COMPLETED

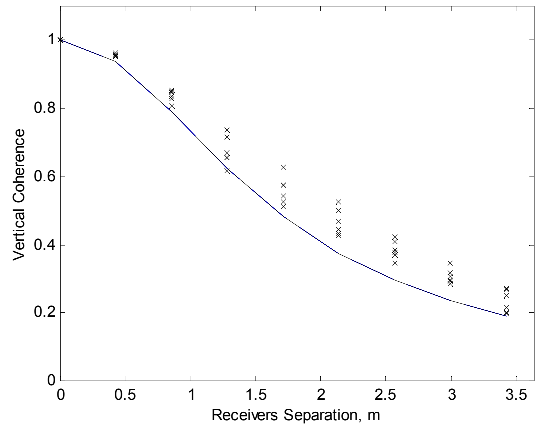
Analytical expressions, based on simplifying assumptions, are derived for the spatial coherence of interface and volume scattering [3] and used to illustrate the potential for separating and quantifying interface and volume scattering. A Monte-Carlo simulation technique that avoids these simplifications is also developed. These simulations are based upon the point scatterer model and make it possible to generate random time series for the scattered signal. An algorithm for data processing is proposed to estimate spatial correlation as an average over realizations (from separate pings) of the measured time series. The simulations are used to illustrate the ability of the algorithm to distinguish and separate volume and surface component of the scattered field. These simulations are also used to verify the simple analytical expressions for spatial coherence.

The Monte-Carlo algorithm is used as follows. Consider a volume of sediment with a number N_v of identical independent scatterers is uniformly distributed within this volume at random positions r_j, $j = 1,...,N_v$. Analogously, a number N_s of identical independent scatterers uniformly distributed on the surface of the sediment volume at positions R_n, $n = 1,...,N_s$. Using a Monte-Carlo approach, we change the positions of the scatterers randomly. Given positions of the two receivers (1 and 2) with fixed vertical separation, we obtain a number (M) of random realizations for both the volume and surface components of scattered field p_{1m} and p_{2m}, $m = 1,...,M$. Then we can calculate the spatial coherence coefficient for both components taking an average over M realizations of the field (number of independent measurements). If M is sufficiently large, the result can be predicted using analytical expressions [3]. Analysis of convergence can permit estimation of the number of realizations which is sufficient for such a prediction. It shows, for example, that longer pulses require a larger number of measurements (realizations).

An illustration of this procedure is given in Figures 1(a,b). The number of both types of scatterers, in the sediment volume and on its surface, was set to 100, and number of realizations used for averaging, M=60. Figure 1 shows the results of Monte-Carlo simulations of surface (a) and volume (b) components of scattering. The curves correspond to the theoretical estimates for the coherence magnitude. It is easy to see that the convergence to the theoretical predictions indeed takes place.



(a)



(b)

Figure 1. Magnitude of the coherence coefficient for surface (a) and volume (b) scatter at 60 realizations.

RESULTS

It is shown that the correlation scales for the volume and surface components of the field scattered by the seafloor can be significantly different, and thus spatial filtration can be used for separating these components. A correlation method for separating and discriminating volume and surface components is proposed, which involves measurements of spatial coherence of the field with a linear array located near the source. This method would also permit separate measurement of the scattering cross section per unit area of bottom surface, the scattering cross section per unit volume and sound attenuation in the sediment.

A point scatterer model for seabed surface and volume is used to illustrate the algorithm. Monte-Carlo simulations based upon the point scatterer model demonstrate the practical applicability of the method. The convergence to the theoretical prediction for both volume and surface components of scattering indeed takes place, but longer pulses require a larger number of measurements (realizations). Thus Monte-Carlo simulations are important for planning optimal parameters for seafloor scattering experiments.

IMPACT/APPLICATIONS

The models of seabed scattering developed in this research will provide a better understanding of bottom acoustic interaction at mid- and high-frequencies and can be used as a basis for improved algorithms for remote acoustic inversions for seafloor properties.

TRANSITIONS

The results of this work are being adapted in practical models for seabed scattering. For example, a high-frequency bistatic scattering model funded by the ONR Torpedo Environments Program (6.2) incorporates the seabed scattering model developed as part of this work. The correlation method for identification and/or separation of the volume and roughness components of scattering was proposed for using during ASIAEX and other ONR experiments.

RELATED PROJECTS

This research is conducted jointly with the separately funded work of D.R. Jackson and T.K. Stanton. The approaches and models developed in this research are relevant to acoustic penetration and volume scattering issues arising within the ONR Departmental Research Initiative on high-frequency sound interaction with the seafloor.

PUBLICATIONS

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